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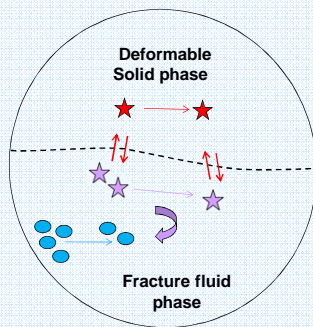
The importance of local thermal non-equilibrium in the modeling of a fractured hot dry rock reservoir

Rachel Gelet⁽¹⁾, Benjamin Loret⁽²⁾

Abstract Thermal recovery from a HDR reservoir, viewed as a deformable fractured medium, is investigated with a focus on the assumption of local thermal non-equilibrium. The numerical model is used to investigate the coupled thermo-hydro-mechanical behavior of the Fenton Hill site. The time profile of the outlet fluid temperature displays a double-step pattern, a feature which is interpreted as characteristic of established local thermal non-equilibrium.

The constitutive model uses a two-phase mixture and accounts for:

- ✓ Generalized diffusion
 - Hydraulic (Darcy) \rightarrow ●
 - Thermal (Fourier) \rightarrow ★
- ✓ Thermal convection \rightarrow ↻
- ✓ Heat transfer \rightleftarrows



The significant contribution is
the local thermal non-equilibrium

★ ≠ ★

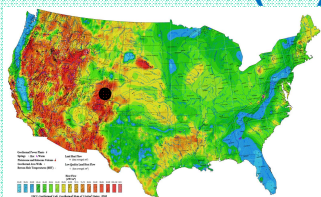
Characteristic times

$$t_{\text{Fourier, frac.}} < t_{\text{Fourier, solid}} < t_{\text{Convection, frac.}} < t_{\text{Darcy, frac.}}$$

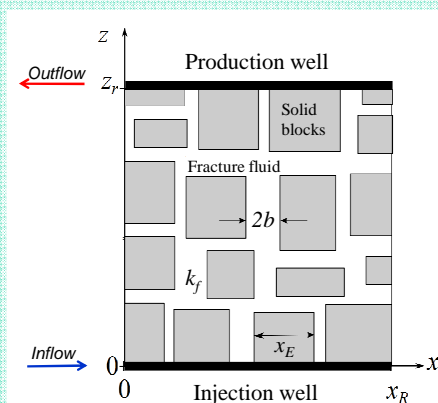
$$10\,000 \text{ years} < 1\,500 \text{ years} < [2 \text{ days} - 7 \text{ years}] < 1 \text{ hour}$$

- Large difference in characteristic times between thermal diffusion in the solid phase and convection in the fluid phase
- Local thermal non-equilibrium is required to accurately represent the overall thermo-hydro-mechanical behavior
- The thermally induced effective stress will trigger thermal shrinkage across the body of the reservoir that may lead to permeability change and fluid loss

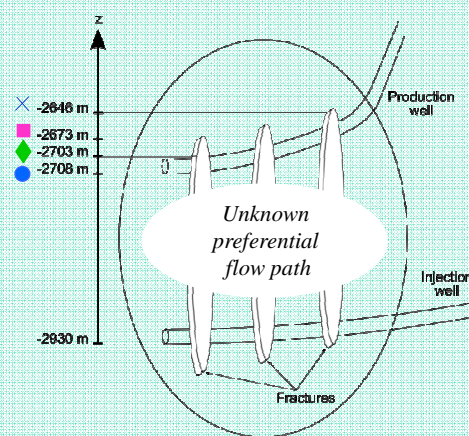
Site: Fenton Hill (US)



Numerical setup



Compared with experimental data

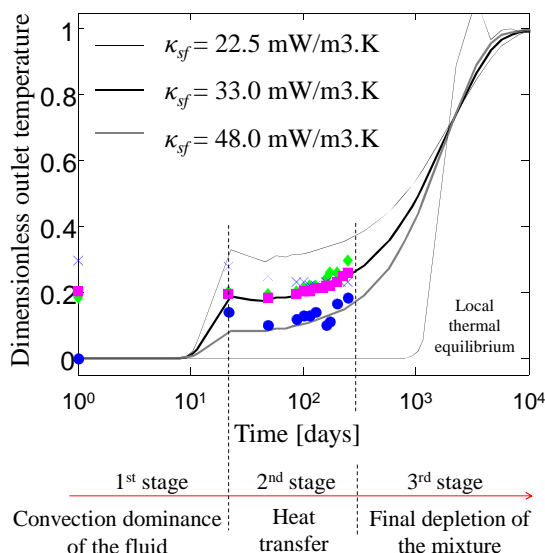


FE Simulation tools

- SUPG method
- Non-linear analysis treated with a Newton-Raphson algorithm
- Fortran language

THM coupled Results: relative temperature outlet versus time along the production well:

- Three parameters of the model are calibrated, namely the permeability $k_f = 8.0$ mD, the porosity $n_f = 0.005$ and the specific inter-phase heat transfer coefficient $\kappa_{sf} = 33.0$ mW/m³.K
- Three stages characteristic of local thermal non-equilibrium are identified
- Local thermal non-equilibrium is characterized by a double step curve, while local thermal equilibrium is recognized by a single-step pattern



Summary

- Numerical results compare well with experimental ones

- The thermal drawdown curve is characterized by three stages, characteristic of local thermal non-equilibrium

Perspectives

Start experimental CHM and THM measures on real samples (ANR project in development)

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